III-15.01 Introduction

This section discusses foreslopes at areas with fills (over 7' deep), steep foreslopes (slopes steeper than 3:1), and box culverts (or other culverts.) Because of terrain, right-of-way, and other issues it may not be possible to eliminate the steep slope or extend the box culvert. Providing recoverable foreslopes (4:1 or flatter) adjacent to the roadway in these areas can give an errant vehicle the necessary room to recover and avoid the steep foreslopes and box culverts.

The configuration of the foreslope cross sections used in areas of fills (over 7' deep), steep foreslopes, and box culverts is based upon the forecast ADT as shown in the Project Concept Report and the depth of the fill at the deepest location. The depth of the fill is measured from the toe of the foreslope at the tie in with the ditch bottom to the edge of the finished shoulder (see Figure 1.)

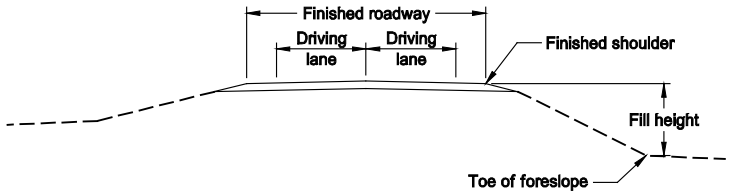

Figure 1 – Fill Height

III-15.02 Foreslope Configuration

The foreslope configurations are divided into two basic groups. The first group has an initial foreslope rate of 6:1 and the second group has an initial foreslope rate of 4:1. The initial foreslope extends to the required clear zone and then continues, breaks to a secondary foreslope, or breaks to a bench section followed by a secondary foreslope (see Figure 2.) The required clear zone values used for the cost effective analysis of the foreslope configurations were taken from Section III-14B of the Design Manual.

The cost effective analysis was completed using various foreslope configurations to determine whether or not to flatten a foreslope. The analysis is based on crash costs, costs to extend box culverts, and costs to install the fill material to flatten the foreslope. The results of the analysis are graphically represented by foreslope configuration, annualized cost, and depth of fill (see Figures 4-15.) Each line represents a different foreslope configuration and is ranked from the lowest being the most cost effective to the highest being the least cost effective.

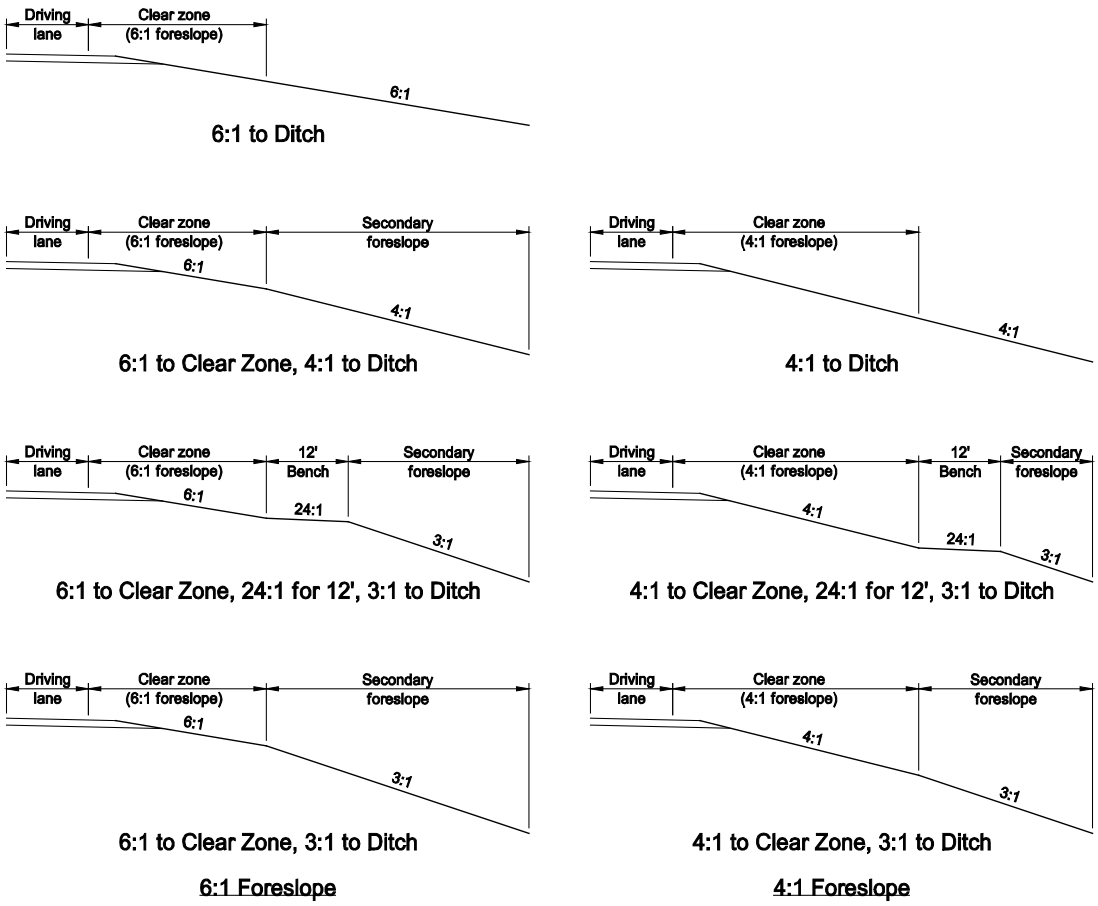

Figure 2 – Foreslope Configurations

It is desirable to choose the most cost effective foreslope configuration based on the graphs. In some cases, site conditions may not allow the most cost effective foreslope configuration to be chosen. All foreslope configurations shown in the graphs are cost effective. Engineering judgment should be used to determine the best possible foreslope configuration based on cost effectiveness and site conditions.

Other foreslope configurations that are not shown in the graphs may be used if shown to be cost effective. The Materials and Research Division must be contacted before considering the use of a foreslope steeper than 3:1. Foreslopes with a rate steeper than 3:1 will normally require a soil stability analysis to show soil conditions are adequate to allow the use of such a foreslope. A bench section with a 12' wide 24:1 slope beginning at the clear zone is desirable with any foreslope steeper than 3:1 to provide a buffer for errant vehicles that may go beyond the clear zone.

III-15.03 Foreslope Transitions

Foreslope transitions should be used anytime the foreslope changes slope rates. Flatter foreslopes tend to allow vehicles to recover quicker, so they do not require as much clear zone distance. Because each foreslope will have a different required clear zone distance, a transition area should be provided between the clear zones. Using the transition will minimize the chance of an errant vehicle crossing between areas with different clear zones.

The foreslope transition should follow the errant vehicle's predicted runout path. The runout path is the line that connects the point at which the vehicle is assumed to leave the traveled way to the outside edge of the clear zone at the area of concern. The area of concern in this case would be the second foreslope. The point of departure would then be at the edge of the driving lane at a distance equal to or greater than the runout length measured upstream along the roadway from the point where the second foreslope extends to the clear zone. The runout length can be found in Section III-13 of the Design Manual. The foreslope transition would then start where the runout path intersects the finished shoulder. Figure 19 in Example 1 shows how to transition from a 4:1 foreslope to a 6:1 foreslope at an area with a fill (over 7' deep). For horizontal curves, the runout path should be adjusted to have the same degree of curvature as the roadway with an adjusted clear zone for the curve.

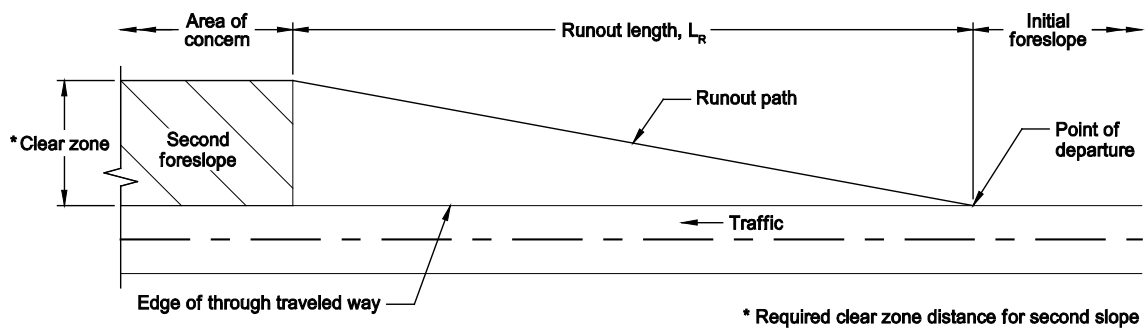

Figure 3 – Runout Path

Typically, foreslopes are transitioned from a 4:1 to a 6:1, but using foreslopes that are 10:1 or flatter can reduce the required clear zone even further. In any case, the foreslope rate in the transition area should have the same rate as the foreslope in the area of concern.

III-15.04 Standard Foreslope vs. Flattened Foreslope

The foreslope rate at the obstructions such as box culverts, structural plate pipes, water over 2' deep, riprap, etc. should meet or exceed the desirable foreslope rate as shown in the Design Guidelines (Section I-06.03 of the Design Manual.) Using a foreslope that is flatter than the standard rate will reduce the required clear zone making it possible to place obstructions that are laterally constrained due to site conditions at or beyond the clear zone. Clear zone values can be found in Section III-14B of the Design Manual.

III-15.04.01 Box Culverts and Structural Plate Pipes

Using a foreslope that is flatter than the standard foreslope rate can sometimes reduce the length of a box culvert or structural plate pipe extension. To determine when to use a flatter foreslope, project a line with the standard rate until it ties into the top of the box culvert (see Figure 4.) If the line ties into the top of the box culvert inside of the clear zone, a flatter foreslope with a reduced clear will usually result in a shorter box culvert extension. If the line ties into the top of the box culvert at or beyond the clear zone, a flatter foreslope with a reduced clear zone will usually result in a longer box culvert extension. The foreslope configuration to be used can then be determined as stated in Section III-15.02 – Foreslope Configuration. A foreslope transition should be used to transition from the flatter foreslope to the standard foreslope. Figure 20 in Example 2 shows how to transition from a 4:1 foreslope to a 6:1 foreslope at a box culvert.

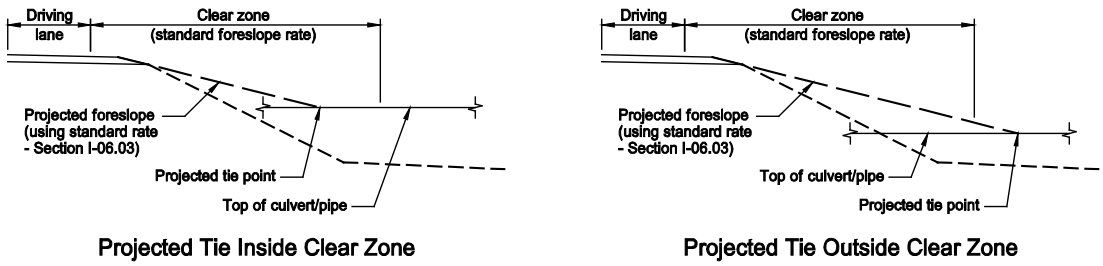

Figure 4 – Foreslope Flattening at Box Culvert or Structural Plate Pipe

III-15.04.02 Water Over 2' Deep and Riprap

Using a flatter foreslope at locations where water over 2' deep and/or riprap is within the clear zone can reduce the amount of fill needed. In cases where the water is high enough to threaten the roadway, a grade raise may be required to increase the elevation of the roadway. The flatter foreslope reduces the amount of vertical drop from the roadway to where the foreslope meets the clear zone, which can reduce the overall height of the grade raise.

Typically, a grade raise has a 10:1 foreslope to the clear zone followed by riprap and a 3:1 slope. See the Earthwork section of the Design Manual for more information on Grade Raises. A foreslope transition should be used to transition from the existing foreslope to the 10:1 foreslopes at the grade raise. Figure 21 in Example 3 shows a foreslope transition from a 4:1 foreslope to a 10:1 foreslope at a grade raise.

III-15.05 State Corridor, District Corridor, and District Collector Highways

This section addresses highways that are classified as a State Corridor, District Corridor, or District Collector. See Section III-15.06 for highways classified as Interregional or Interstate.

The proposed foreslope configuration should be chosen based on the desirable foreslope rate as shown in the Design Guidelines (Section I-06.03 of the Design Manual.) Figures 5-8 show foreslope configurations for a 4:1 foreslope rate and Figures 9-12 show foreslope configurations for a 6:1 foreslope rate.

Foreslopes flatter than those shown in the Design Guidelines may be used in some cases as described in Section III-15.04 – Standard Foreslope vs. Flattened Foreslope.

4:1 Foreslope Configurations

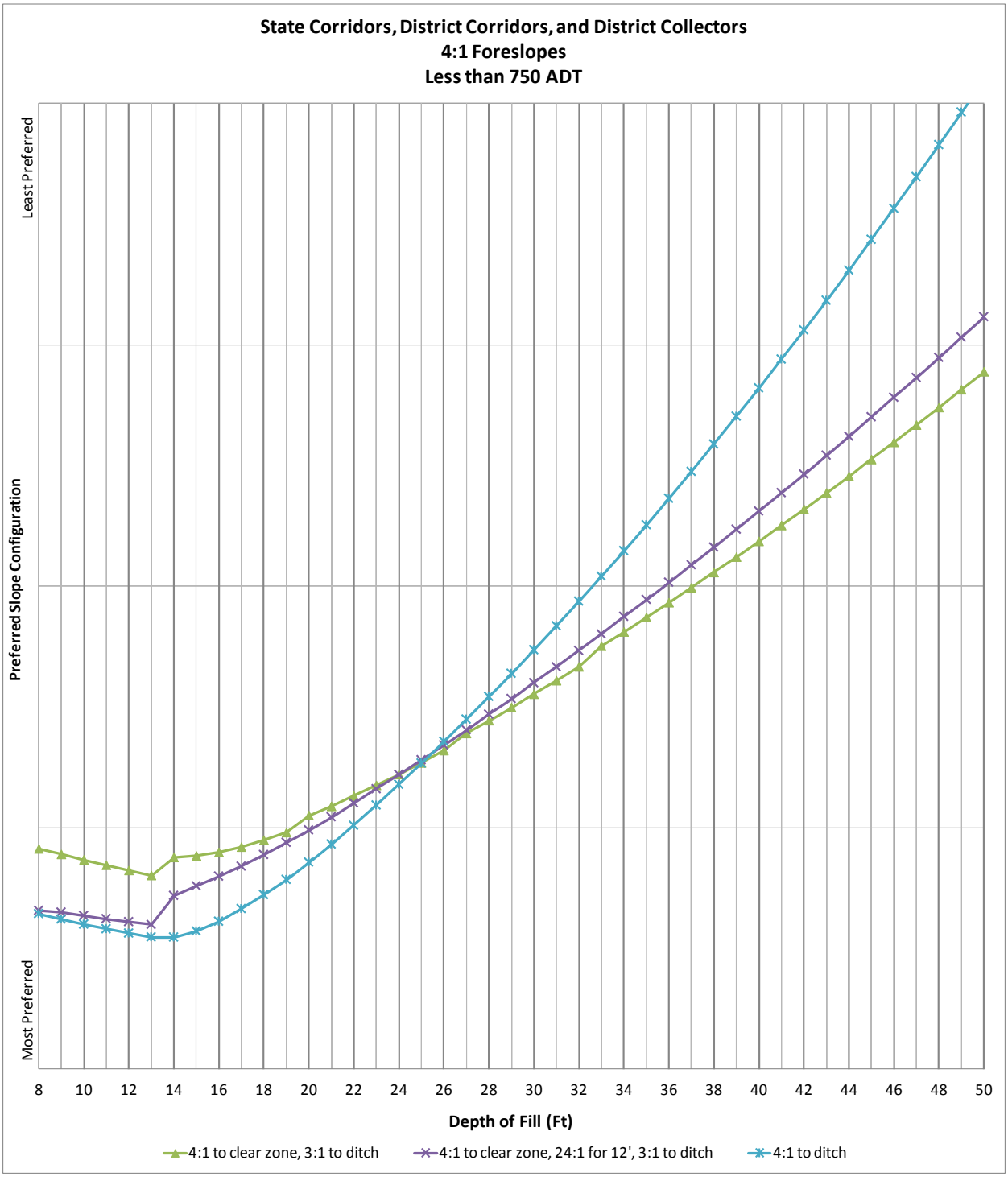

Figure 5 – 4:1 Foreslopes (Less than 750 ADT)

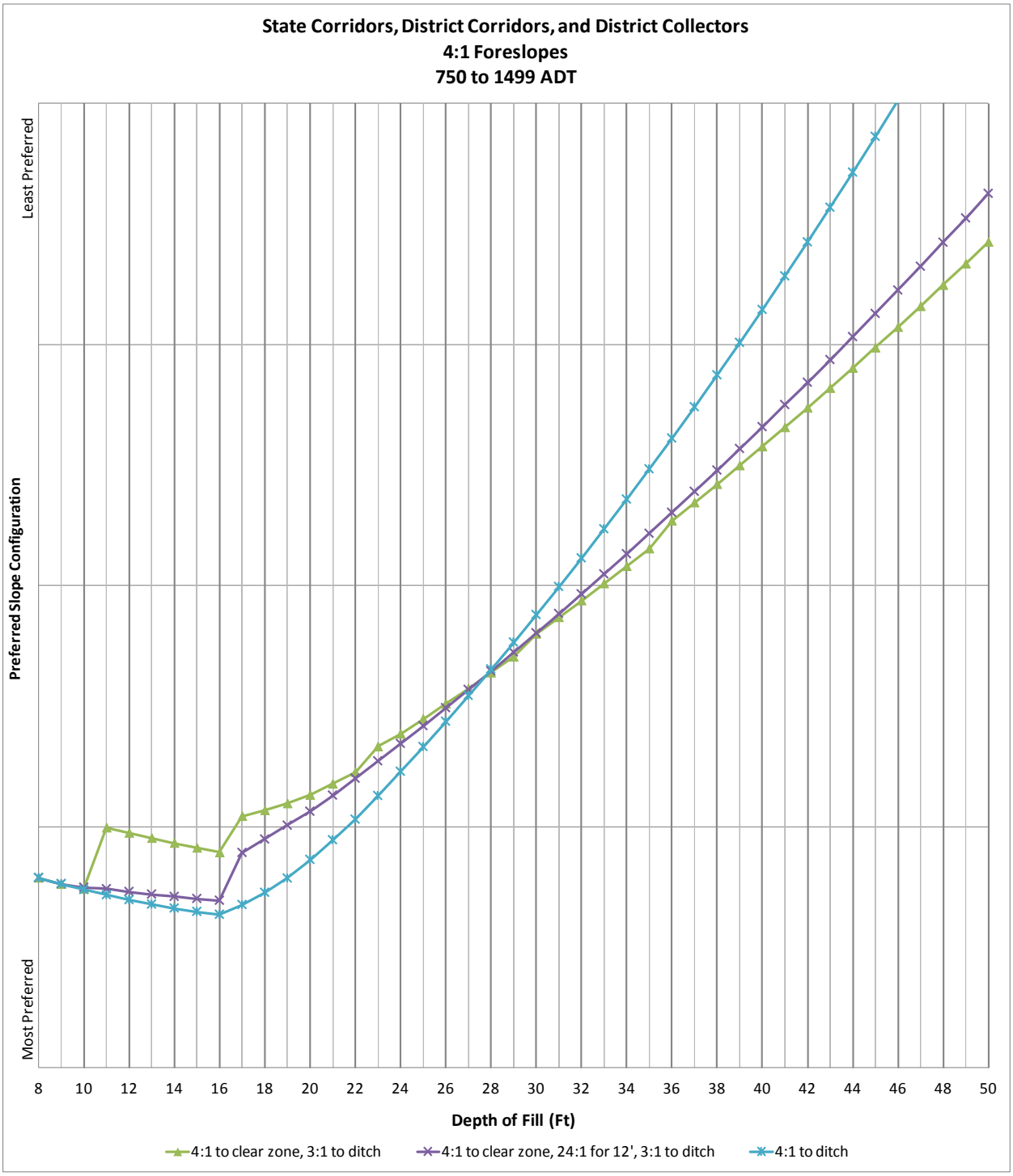

Figure 6 – 4:1 Foreslopes (750 to 1499 ADT)

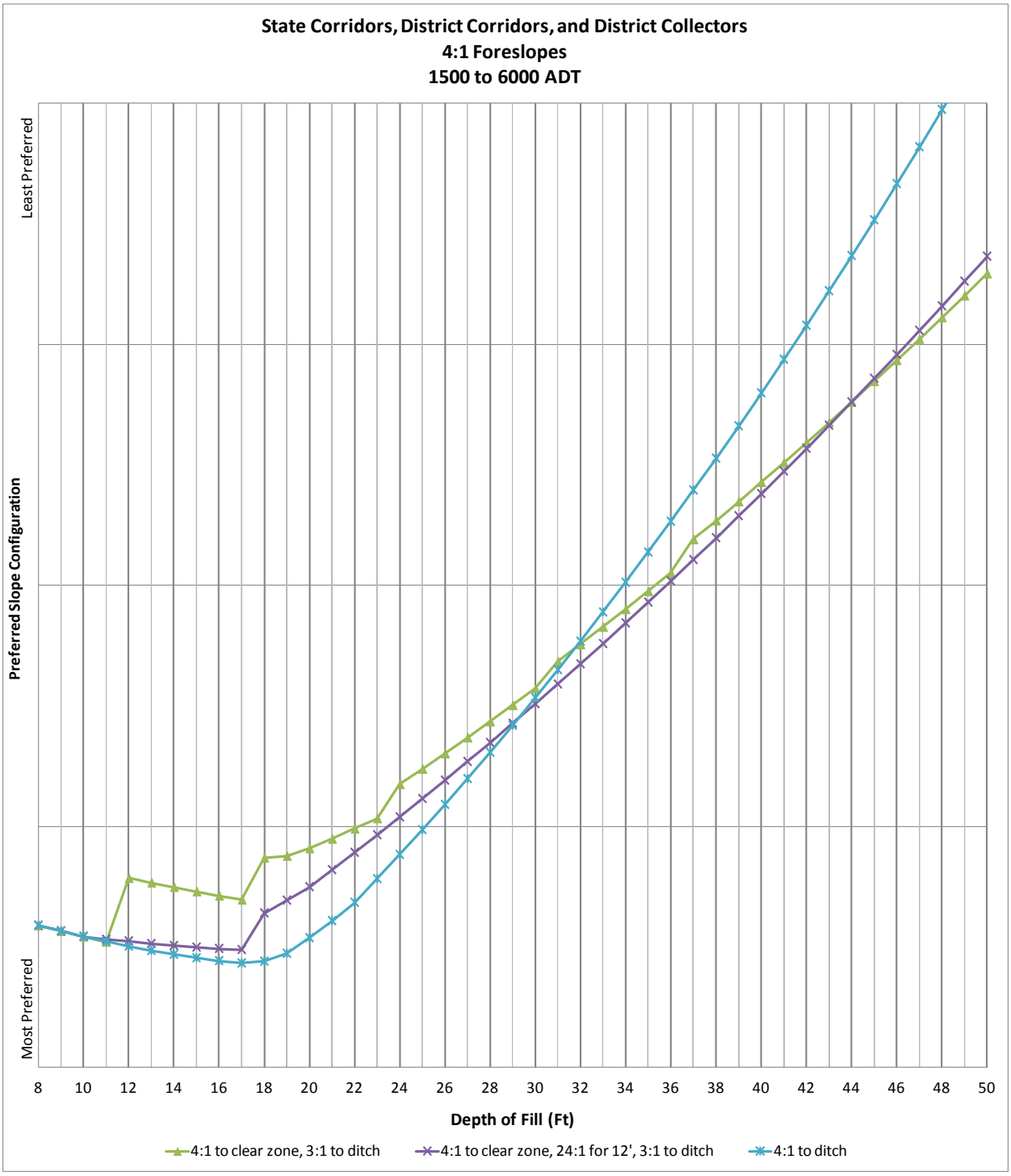

Figure 7 – 4:1 Foreslopes (1500 to 6000 ADT)

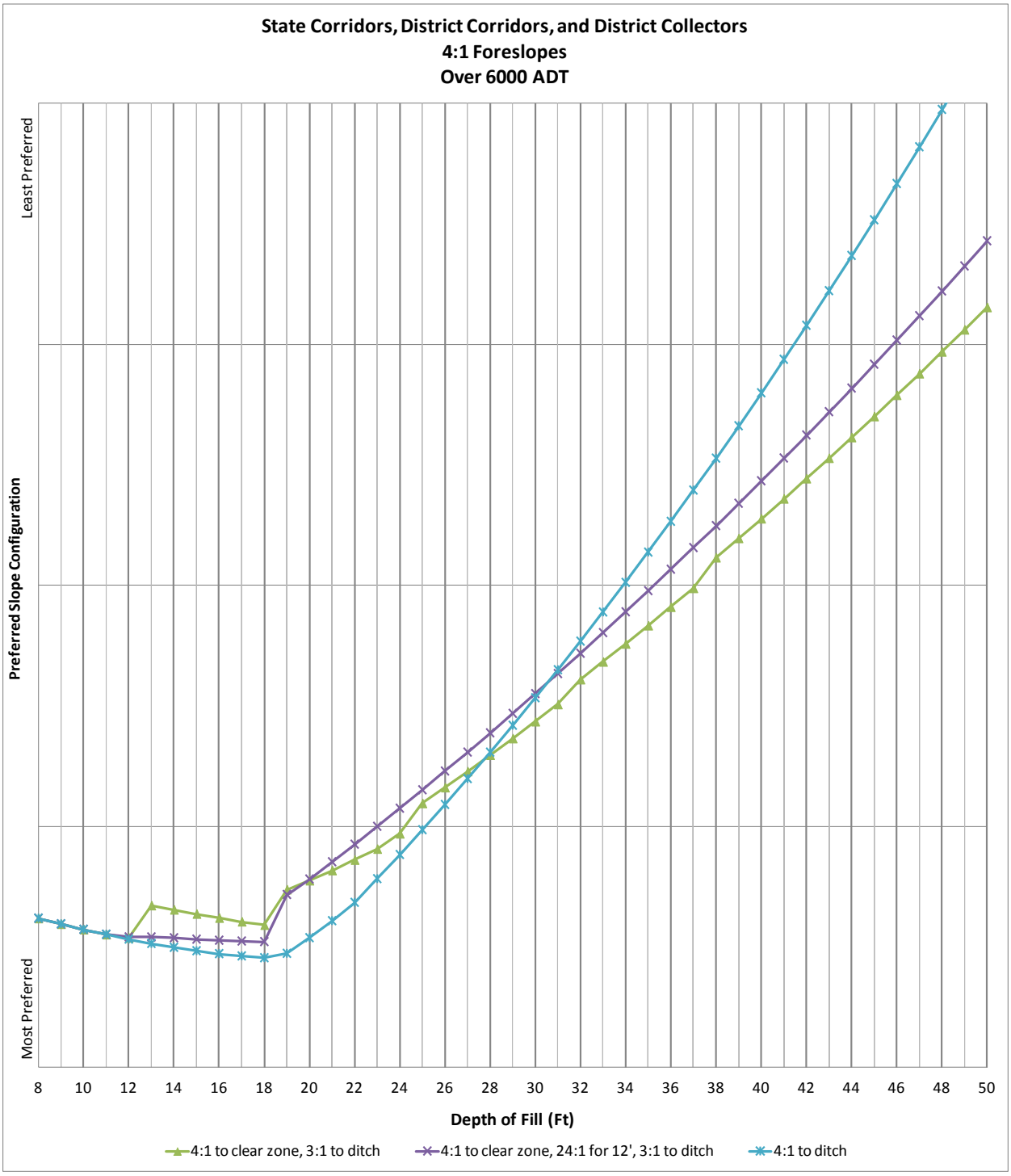

Figure 8 – 4:1 Foreslopes (Over 6000 ADT)

6:1 Foreslope Configurations

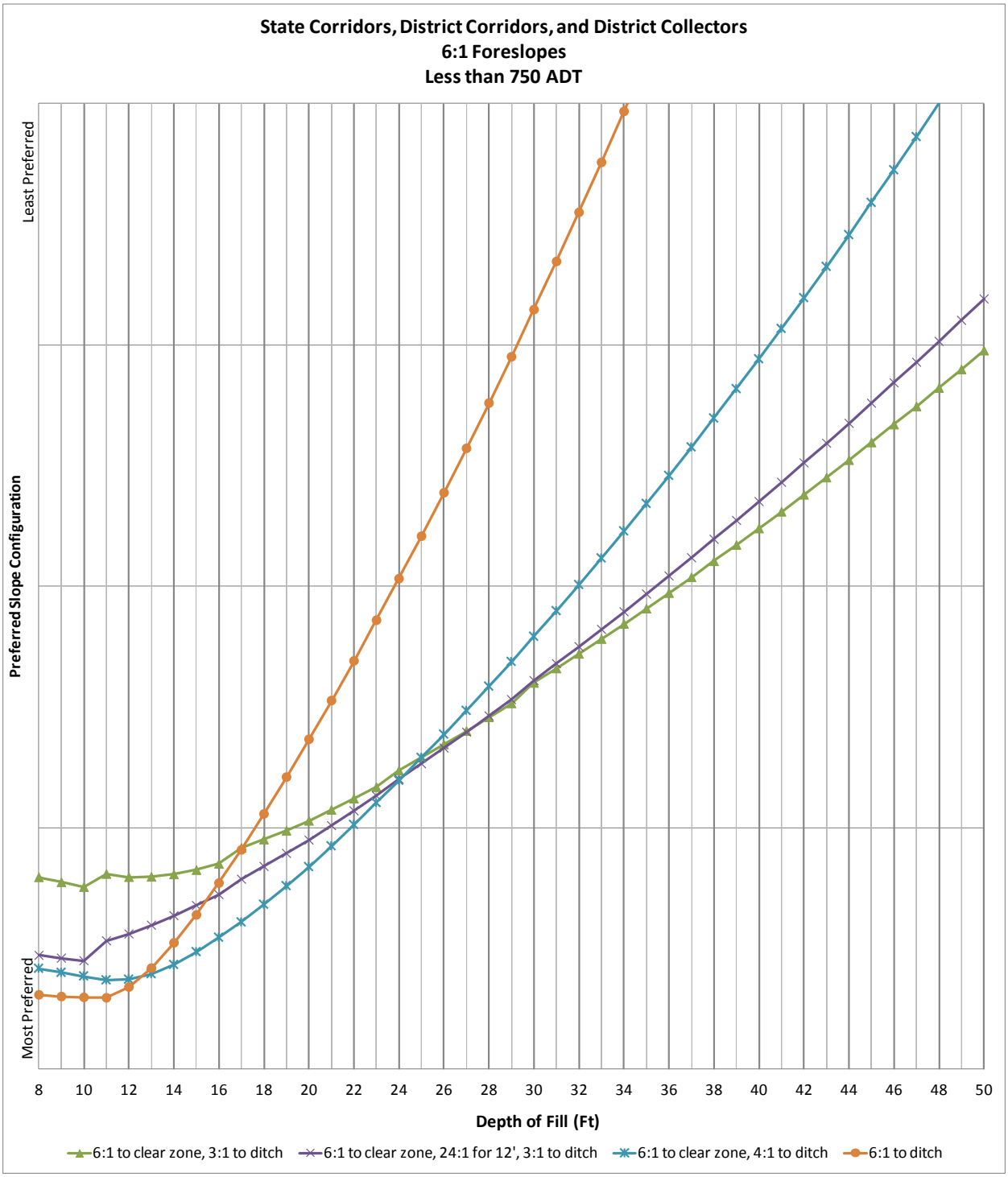

Figure 9 – 6:1 Foreslopes (Less than 750 ADT)

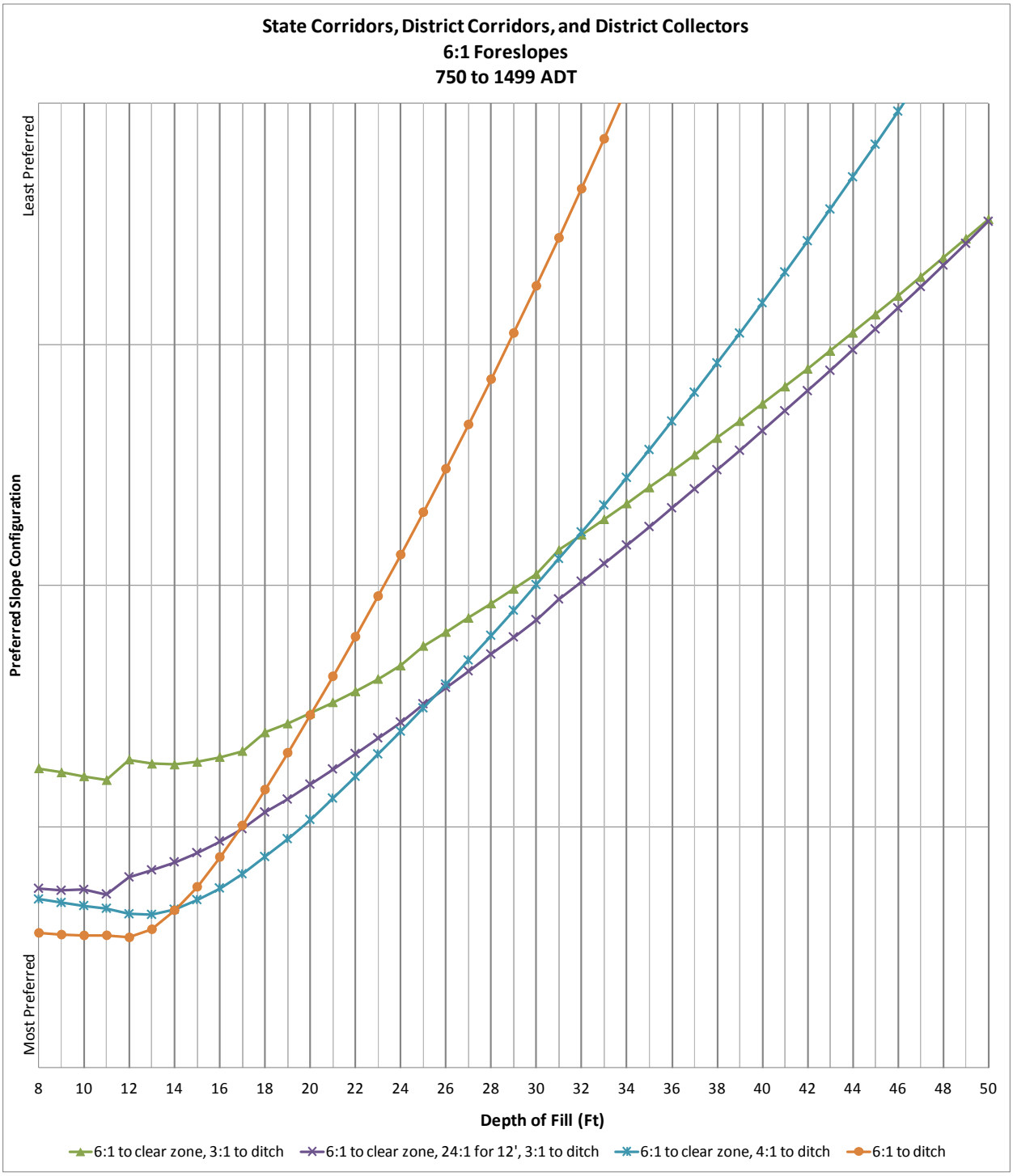

Figure 10 – 6:1 Foreslopes (750 to 1499 ADT)

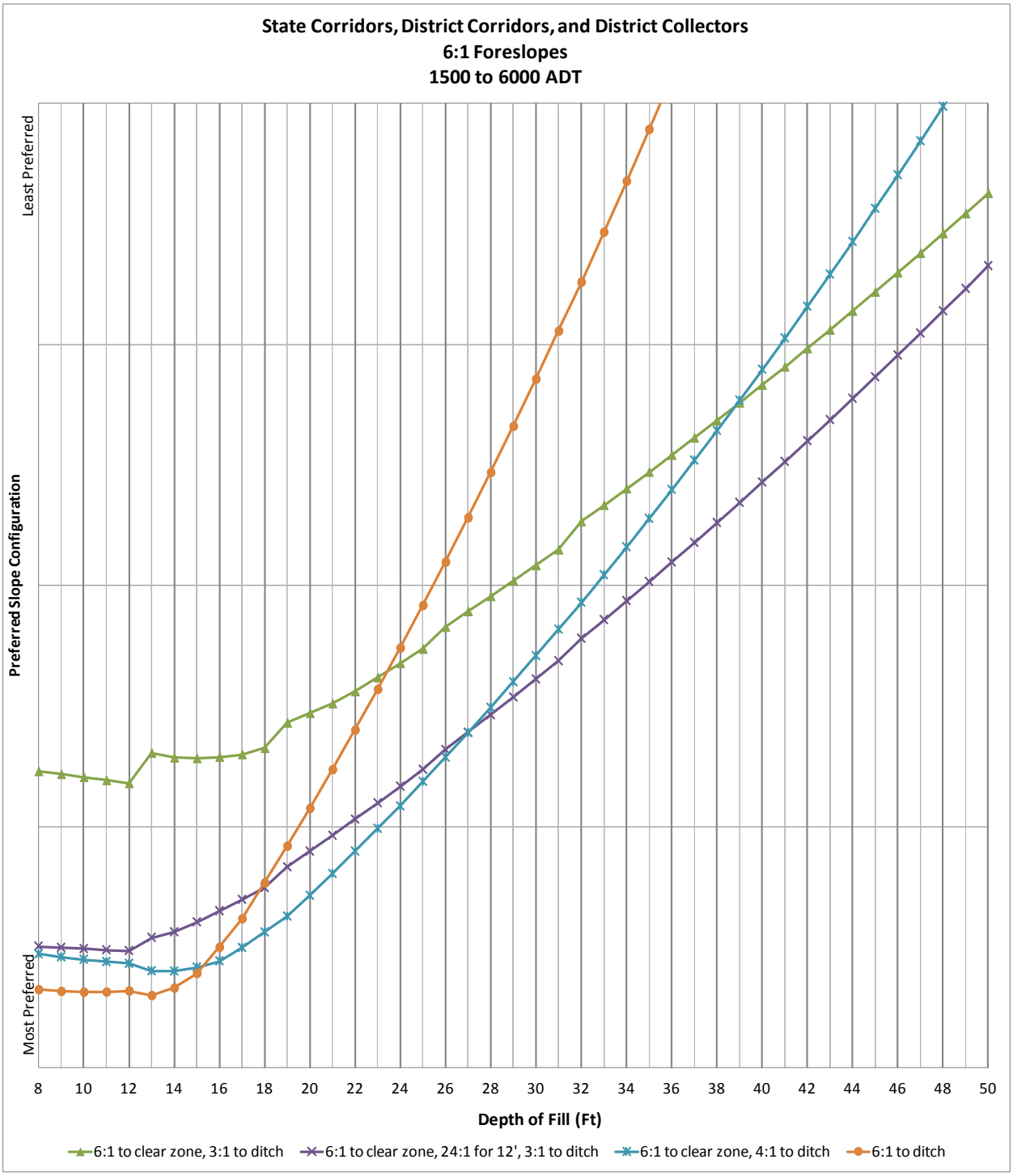

Figure 11 – 6:1 Foreslopes (1500 to 6000 ADT)

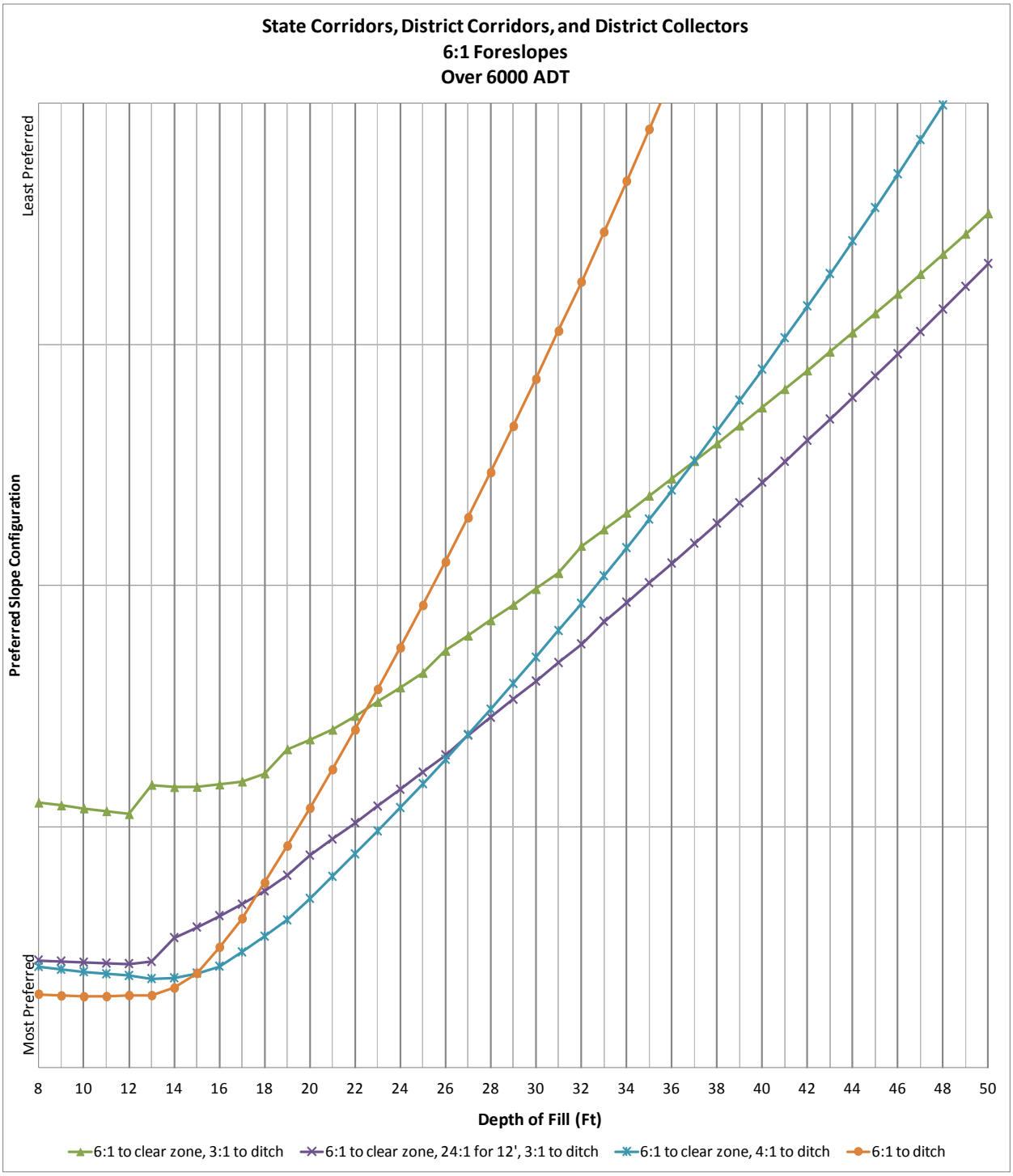

Figure 12 – 6:1 Foreslopes (Over 6000 ADT)

III-15.06 Interregional Highways and Interstate

This section addresses highways that are classified as either Interregional or Interstate highways See Section III-15.05 for highways that are classified as a State Corridor, District Corridor, or District Collector.

The proposed foreslope configuration should be chosen based on the desirable foreslope rate as shown in the Design Guidelines (Section I-06.03 of the Design Manual.) Figures 13-15 show foreslope configurations for a 4:1 foreslope rate and Figures 16-18 show foreslope configurations for a 6:1 foreslope rate.

Foreslopes flatter than those shown in the Design Guidelines may be used in some cases as described in Section III-15.04 – Standard Foreslope vs. Flattened Foreslope.

4:1 Foreslope Configurations

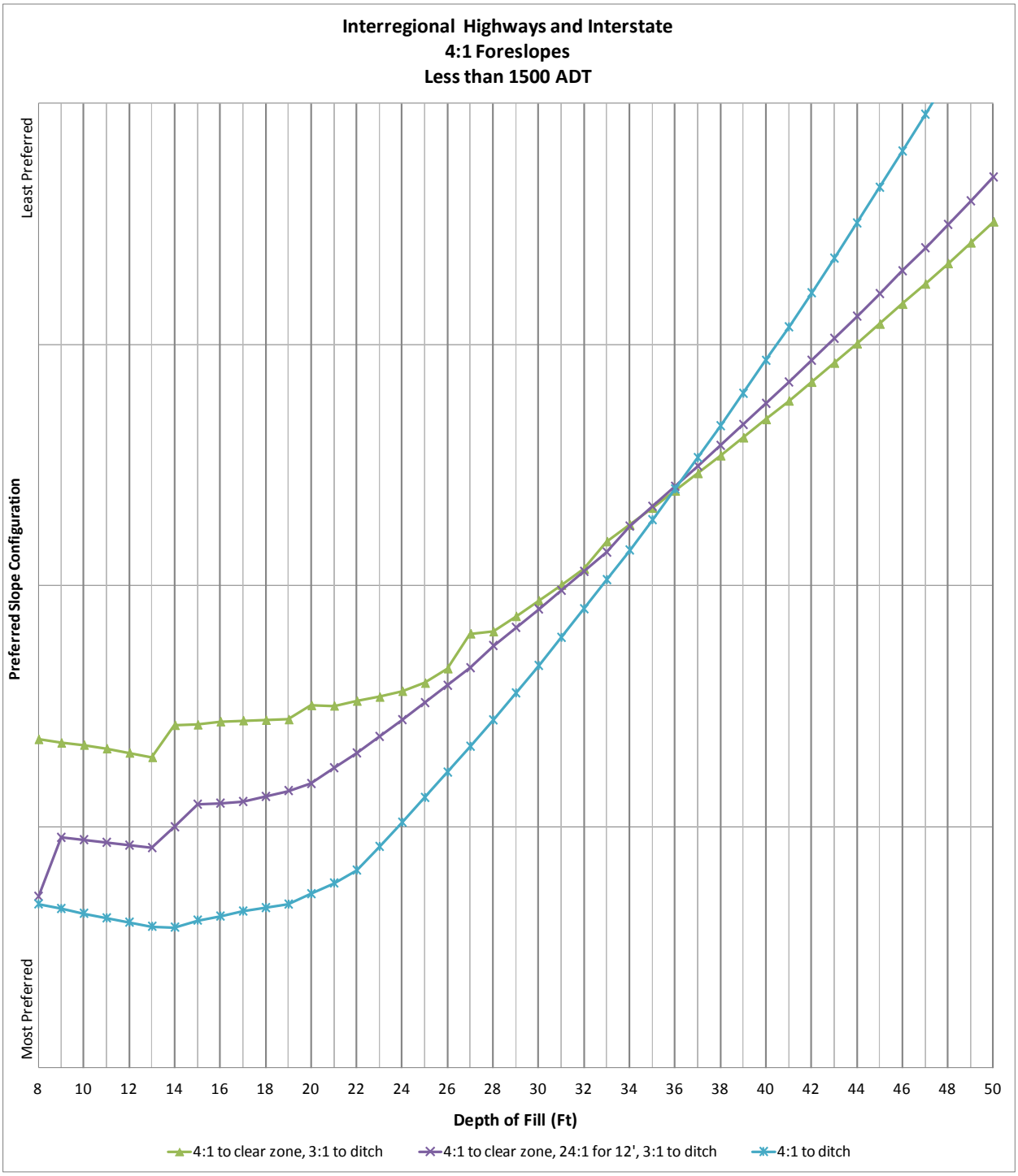

Figure 13 – 4:1 Foreslopes (Less than 1500 ADT)

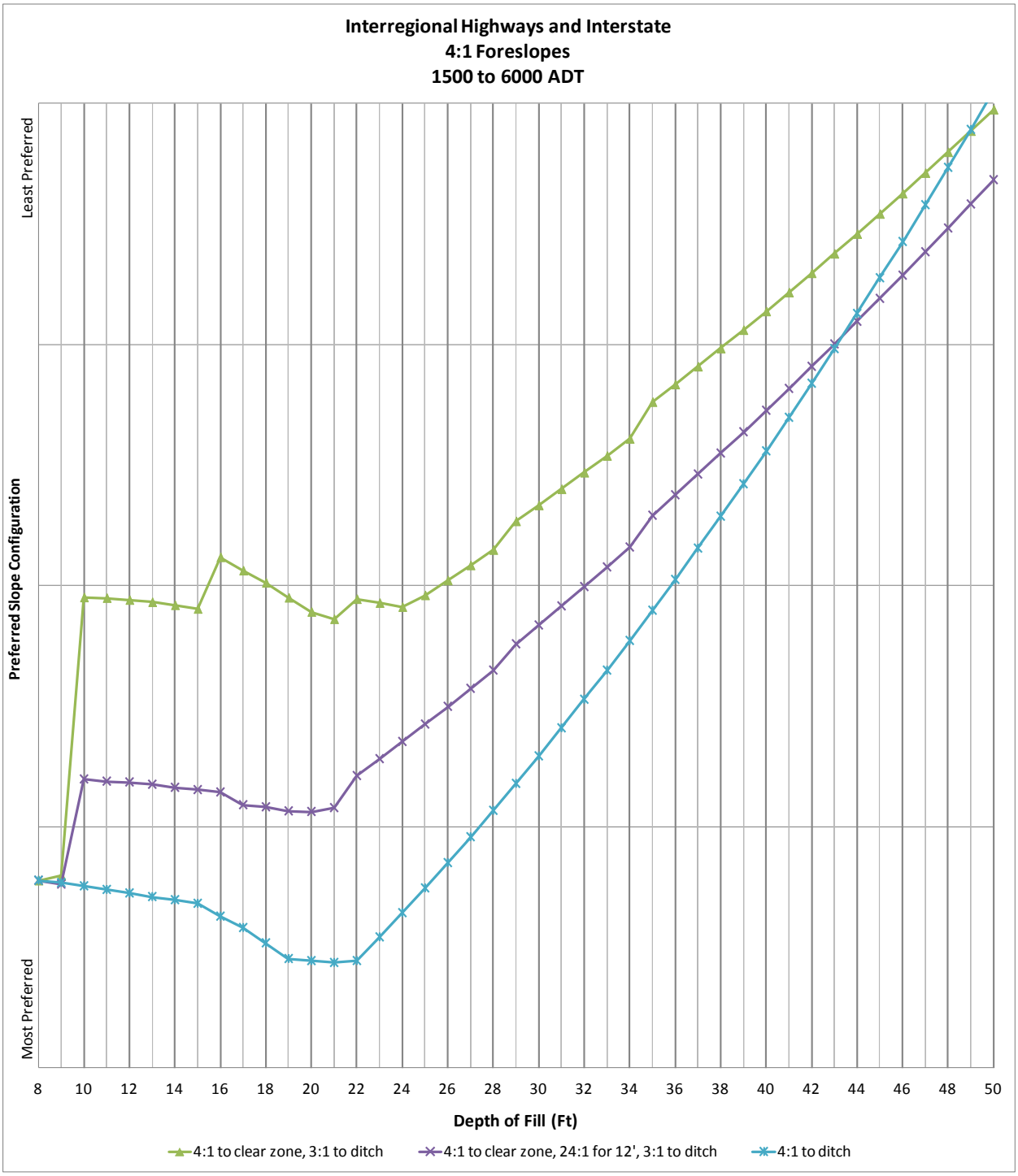

Figure 14 – 4:1 Foreslopes (1500 to 6000 ADT)

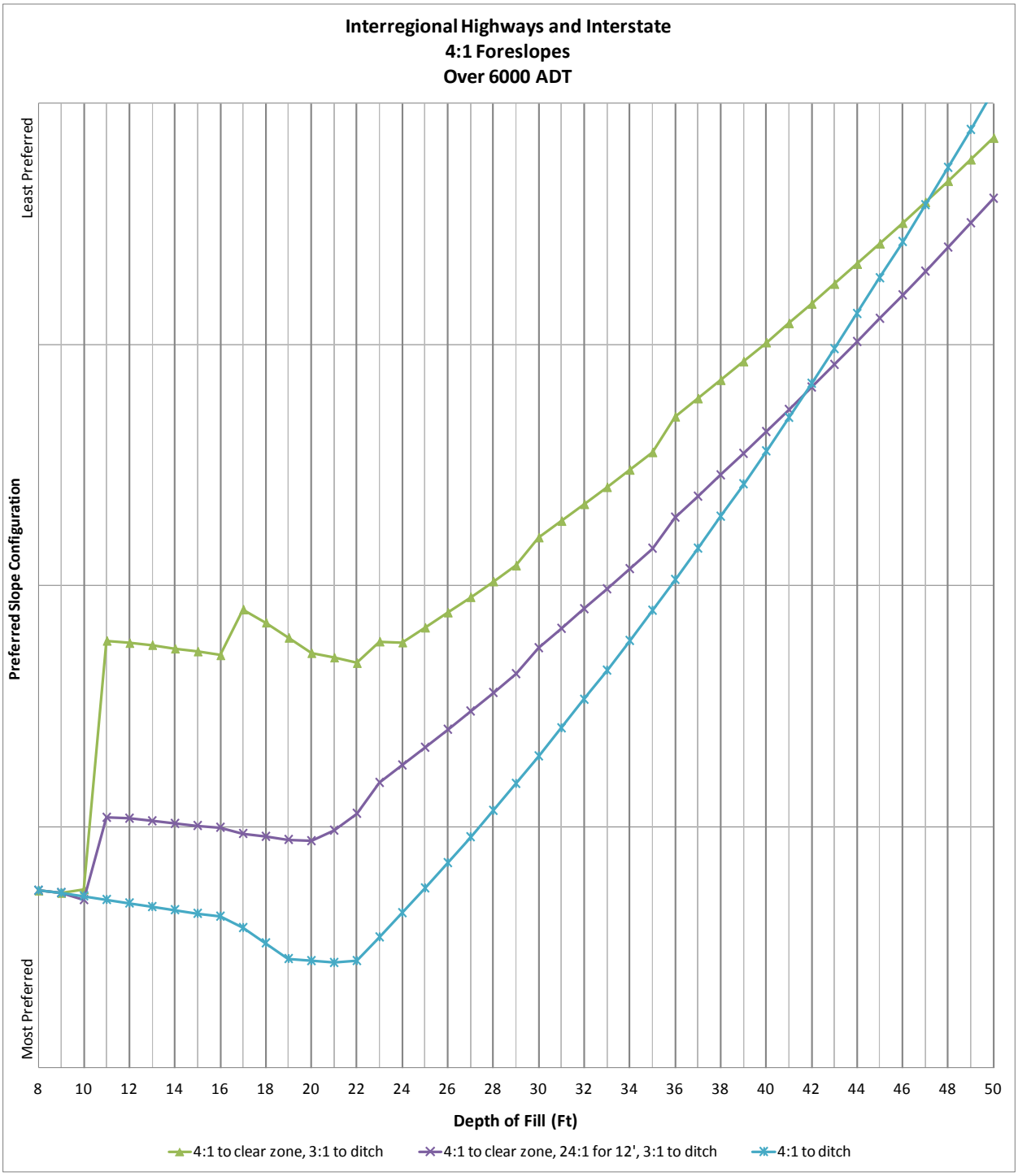

Figure 15 – 4:1 Foreslopes (Over 6000 ADT)

6:1 Foreslope Configurations

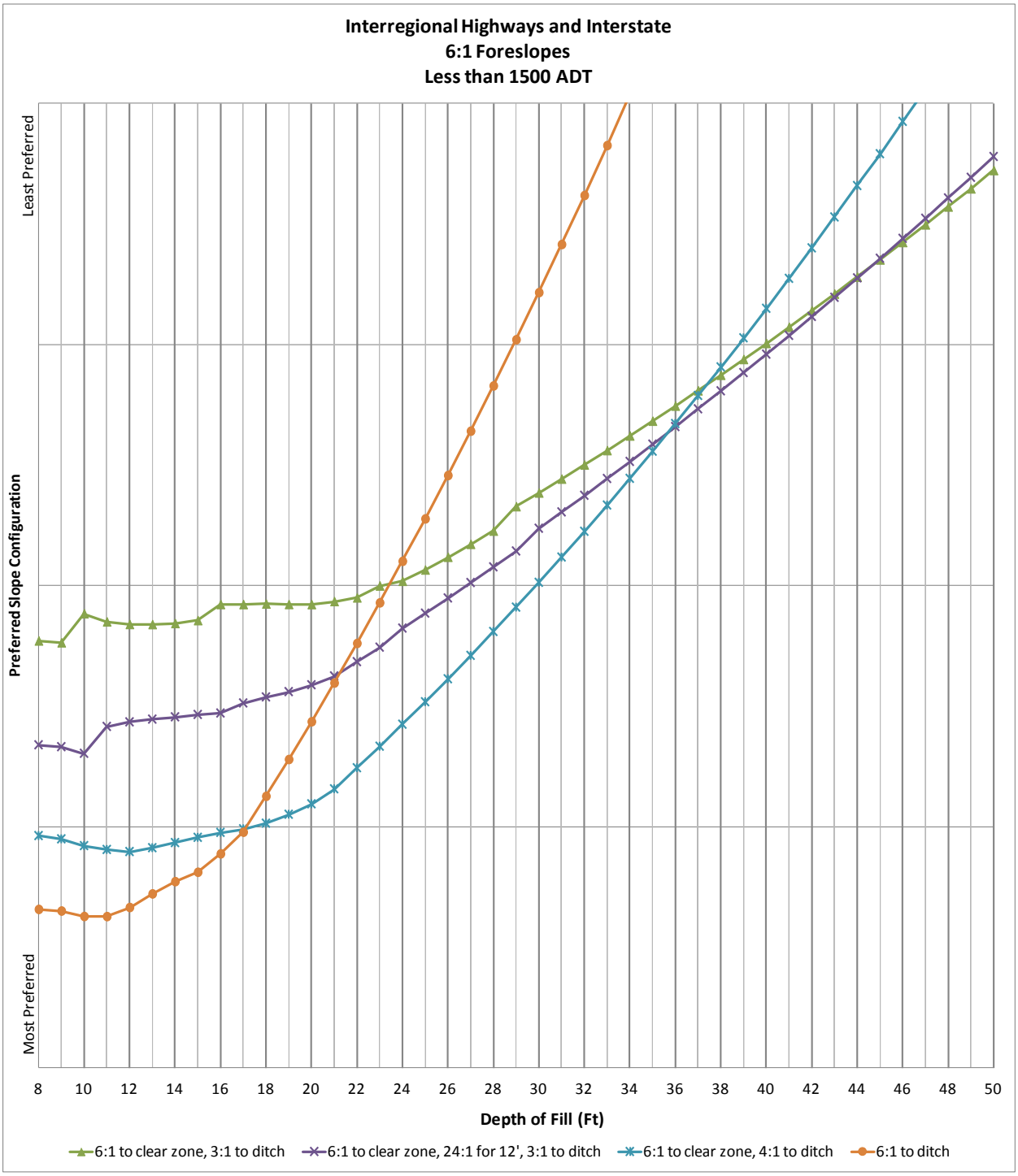

Figure 16 – 6:1 Foreslopes (Less than 1500 ADT)

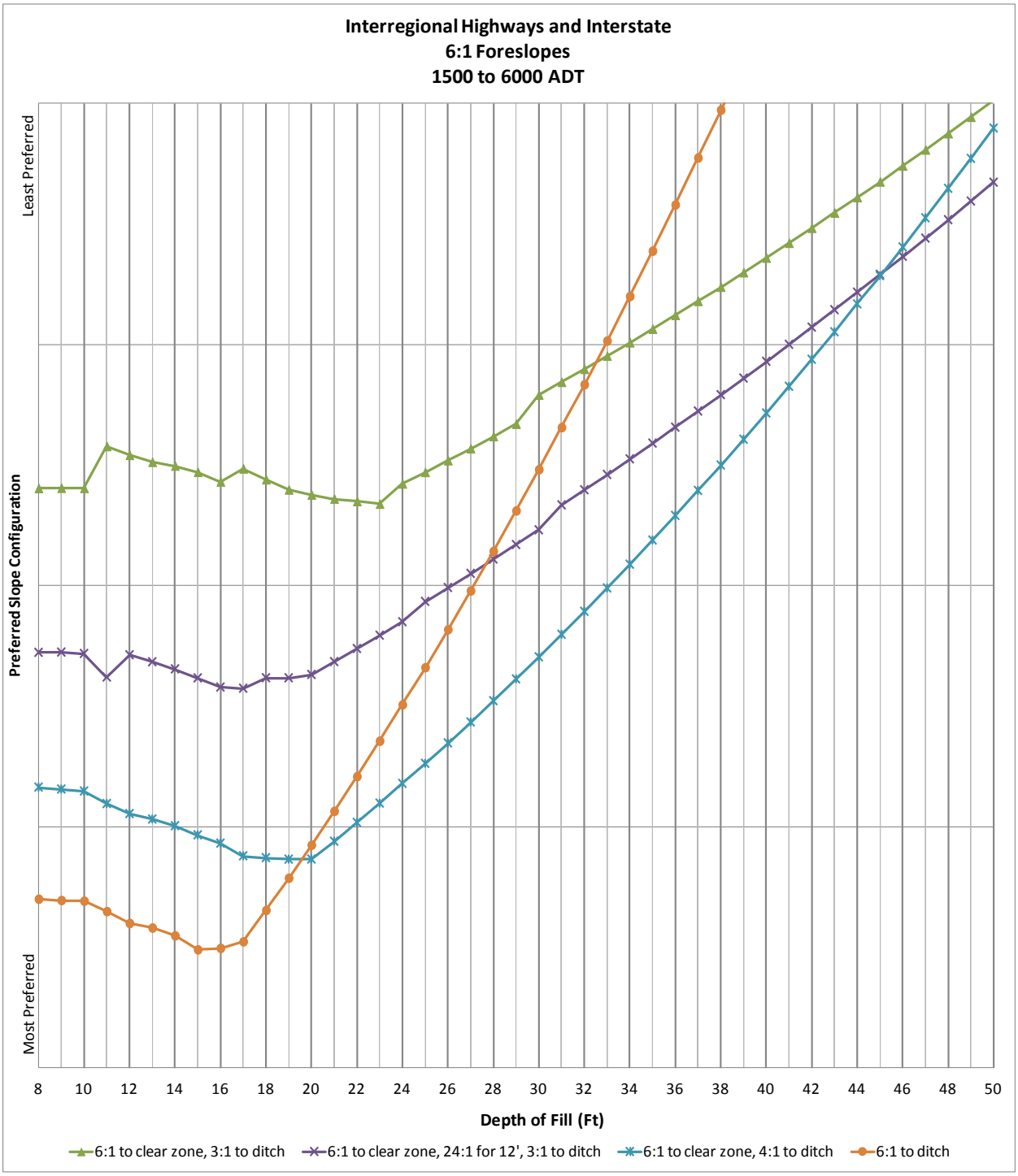

Figure 17 – 6:1 Foreslopes (1500 to 6000 ADT)

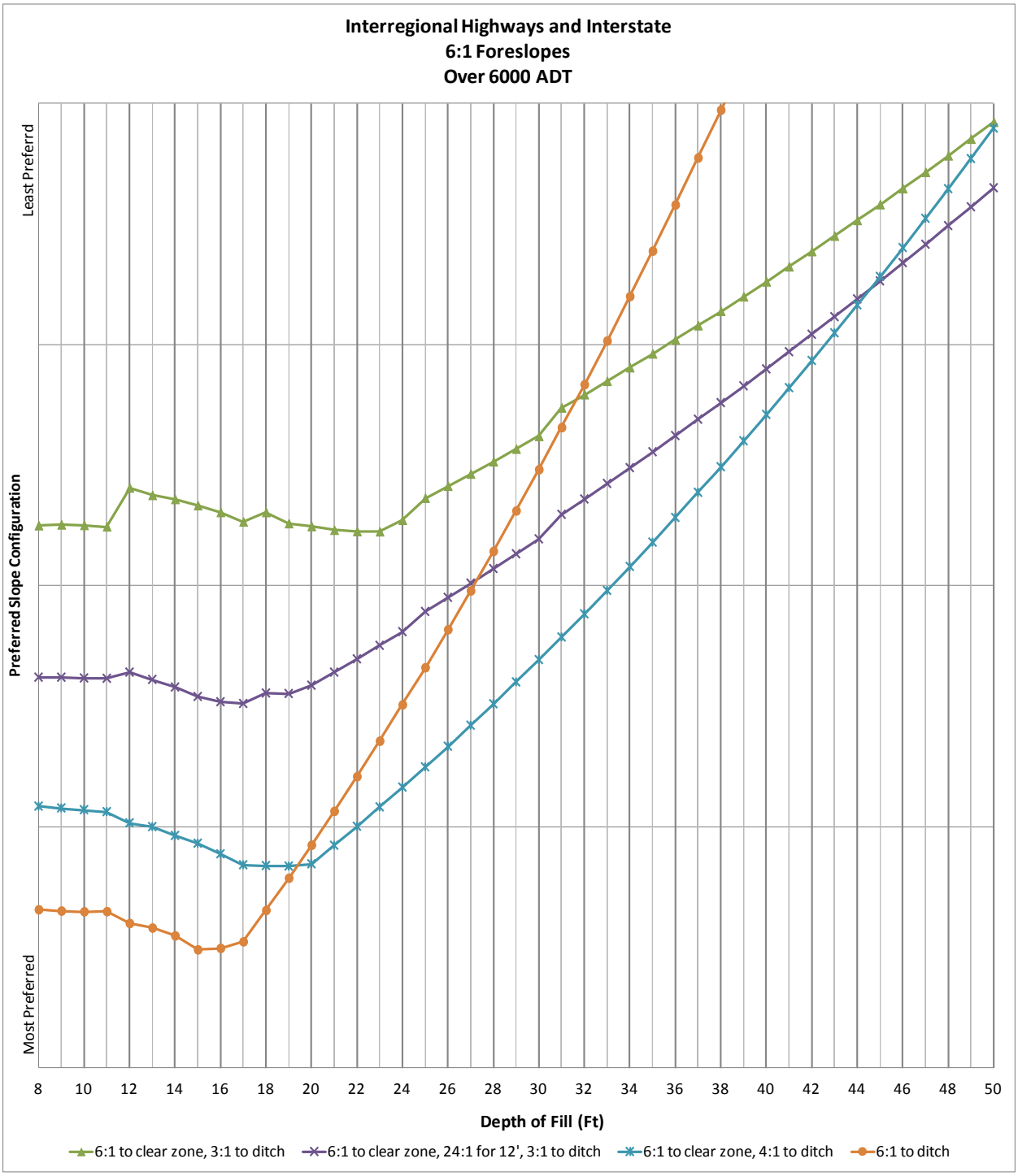

Figure 18 – 6:1 Foreslopes (Over 6000 ADT)

III-15.07 Examples

III-15.07.01 Example 1 – Foreslope Transition at Slide Area

Roadway: Two-Lane Interregional with 4:1 foreslopes
Design ADT: 3500
Design Speed: 65 MPH
Runout Length (Section III-13): 425 ft
Clear Zone for 4:1 foreslope (Section III-14B): 42 ft
Clear Zone for 6:1 foreslope (Section III-14B): 32 ft

There is a slide area within the clear zone. Based on the Design Guidelines the standard foreslope rate for this roadway is 6:1. Because the project is limited to the area of the slide, a foreslope transition will be needed to tie the existing 4:1 foreslopes into the 6:1 foreslopes in the slide area. Refer to Figure 19 for a plan view of the area and cross sections for this example.

Determine which foreslope configuration will be used through the fill area. To do this, find the deepest fill height measured from the toe of the foreslope at the tie in with the ditch bottom to the edge of the finished shoulder. Because the roadway is a two-lane interregional roadway and the design ADT is 3500, Figure 17 will be used. Using the deepest fill height, choose the best possible foreslope configuration. The most preferred foreslope configuration will be the bottom line. For example, for a fill height of 14', the foreslope configurations in order of preference would be: 1) 6:1 to ditch bottom; 2) 6:1 to clear zone, 4:1 to ditch bottom; 3) 6:1 to clear zone, 24:1 for 12', 3:1 to ditch bottom; and 4) 6:1 to clear zone, 3:1 to ditch bottom. The same foreslope configuration should be used throughout the fill section. The most preferred foreslope configuration should be used unless site conditions do not allow it.

Once the foreslope configuration has been determined, the limits of the fill area can be found (Section D-D.) Sometimes it may not be clear where the fill area begins and ends and may require engineering judgment to determine the limits and/or trial and error to find the best place to fit the foreslope transition.

A 25' transition should be used to transition between Section C-C and Section D-D. A transition will not be needed when the foreslope configuration in Section D-D consists of a 6:1 foreslope that breaks to a 4:1 foreslope at the clear zone.

Determine the point at which the foreslope will begin to transition from a 4:1 foreslope to a 6:1 foreslope. The transition will follow the runout path and begin at the point where the runout path intersects the edge of the finished shoulder (Section A-A.) The runout path can be determined using the runout length as stated in Section III-15.03 – Foreslope Transitions. The foreslope rate in the transition area (Section B-B) should have the same rate as the foreslope in the fill area (Section D-D.)

The 4:1 foreslope becomes the secondary foreslope at the start of the transition area (Section A-

A.) The top of the 4:1 foreslope should be at the edge of the 6:1 foreslope along the runout path and the bottom will be where the 4:1 foreslope ties back into the ditch bottom.

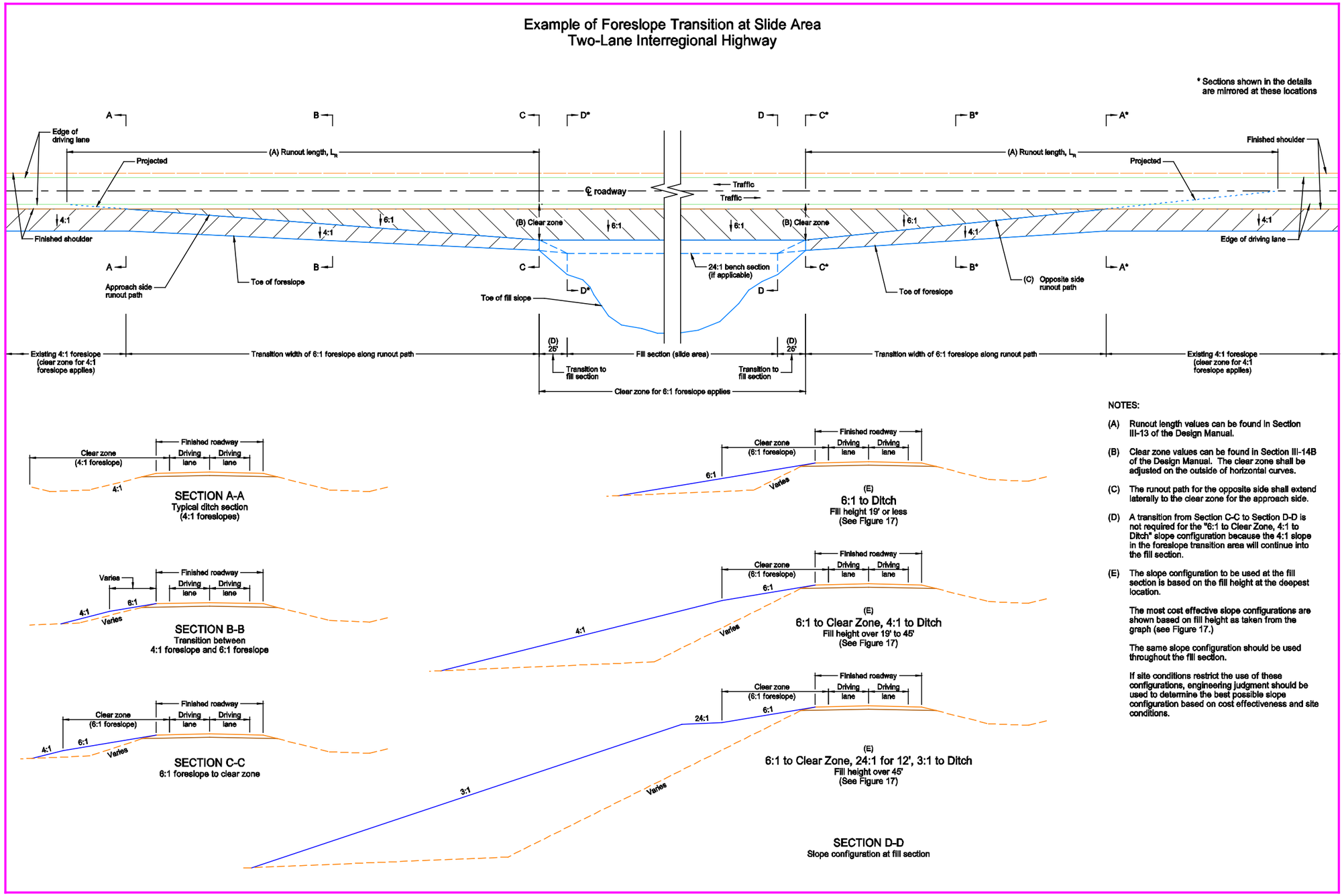

Figure 19 – Example 1 – Foreslope Transition at Slide Area

III-15.07.02 Example 2 – Foreslope Transition at Box Culvert

Roadway: Two-Lane District Corridor with 4:1 foreslopes
Design ADT: 1200
Design Speed: 65 MPH
Runout Length (Section III-13): 370 ft
Clear Zone for 4:1 foreslope (Section III-14B): 36 ft
Clear Zone for 6:1 foreslope (Section III-14B): 26 ft

There is a box culvert within the clear zone. Based on the Design Guidelines the standard foreslope rate for this roadway is 4:1. The decision was made to use a foreslope with a rate of 6:1 at the box culvert to reduce the length of the box culvert extension. A foreslope transition will be needed to tie the existing 4:1 foreslopes into the 6:1 foreslopes at the box culvert. Refer to Figure 20 for a plan view of the area and cross sections for this example.

Figure 20 shows two different scenarios:

1. In the first scenario (left side of Section E-E), the box culvert does not have enough cover fill to fit a 6:1 foreslope and the foreslope must be flattened to tie into the box culvert parapet.
2. In the second scenario (right side of Section E-E), there is sufficient cover and no additional flattening over the box culvert is required.

Determine which foreslope configuration will be used through the area with the box culvert. To do this, find the deepest fill height measured from the toe of the foreslope at the tie in with the ditch bottom to the edge of the finished shoulder. Generally, the deepest height will be at the box culvert. Because the roadway is a two-lane district corridor and the design ADT is 1200, Figure 10 will be used. Using the deepest fill height, choose the best possible foreslope configuration. The most preferred foreslope configuration will be the bottom line. For example, for a fill height of 12', the foreslope configurations in order of preference would be: 1) 6:1 to ditch bottom; 2) 6:1 to clear zone, 4:1 to ditch bottom; 3) 6:1 to clear zone, 24:1 for 12', 3:1 to ditch bottom; and 4) 6:1 to clear zone, 3:1 to ditch bottom. The same foreslope configuration should be used throughout the area even though the fill height may change. The most preferred foreslope configuration should be used unless site conditions do not allow it.

Once the foreslope configuration has been determined, the limits of the area to be flattened can be found (Section E-E.) The minimum length of the area to be flattened should be the length of the box culvert opening plus a 25' buffer on each side of the opening. If the box culvert is in an area with a fill over 7' deep, use the limits of the fill area.

A 25' transition should be used to transition between Section D-D and Section E-E. A transition will not be needed when the foreslope configuration in Section E-E consists of a 6:1 foreslope that breaks to a 4:1 foreslope at the clear zone.

For shallow box culverts, additional flattening may be required directly over the box culvert. A maximum rate of 10:1 (perpendicular to foreslope) should be used between the 6:1 foreslope and the flattened area over the box culvert. The 10:1 slope may overlap the 25' transition between Section D-D and Section E-E.

Determine the point at which the foreslope will begin to transition from a 4:1 foreslope to a 6:1 foreslope. The transition will follow the runout path and begin at the point where the runout path intersects the edge of the finished shoulder (Section A-A on upstream end for approach side traffic and Section B-B on downstream end for opposite side traffic.) The runout path can be determined using the runout length as stated in Section III-15.03 – Foreslope Transitions. The foreslope rate in the transition area (Section C-C) should have the same rate as the foreslope in the fill area (Section E-E.)

The 4:1 foreslope becomes the secondary foreslope at the start of the transition area (Section A-A.) The top of the 4:1 foreslope should be at the edge of the 6:1 foreslope along the runout path and the bottom will be where the 4:1 foreslope ties back into the ditch bottom.

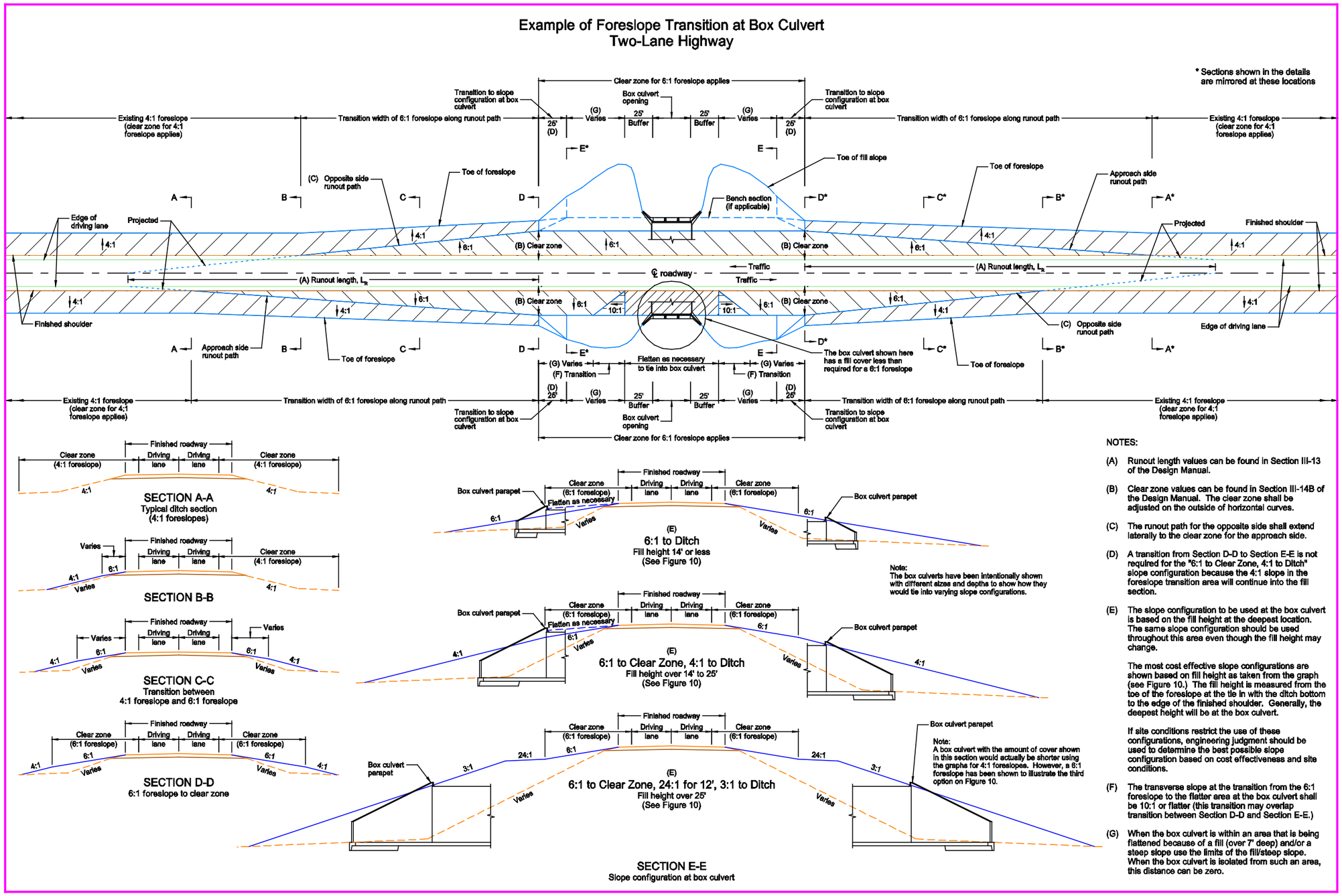

Figure 20 – Example 2 – Foreslope Transition at Box Culvert

III-15.07.03 Example 3 – Grade Raise with Water on One Side Only

Roadway: Two-Lane State Corridor with 4:1 foreslopes
Design ADT: 1000
Design Speed: 65 MPH
Runout Length (Section III-13): 370 ft
Clear Zone for 4:1 foreslope (Section III-14B): 36 ft
Clear Zone for 10:1 foreslope (Section III-14B): 24 ft

There is water over 2' deep within the clear zone on one side of the roadway. Based on the Design Guidelines the standard foreslope rate for this roadway is 4:1. Because of the proximity of the water to the roadway, the decision was made to do a grade raise project. Refer to Figure 21 for a plan view of the area and cross sections for this example.

Water Side

Typically, a grade raise has a 10:1 foreslope to the clear zone followed by riprap and a 3:1 slope. See the Earthwork section of the Design Manual for more information on Grade Raises. A foreslope transition will be needed to tie the existing 4:1 foreslopes into the 10:1 foreslopes at the grade raise.

Determine the limits of the fill section area (Section D-D.) Sometimes it may not be clear where the fill area begins and ends and may require engineering judgment to determine the limits and/or trial and error to find the best place to fit the foreslope transition.

A 25' transition should be used to transition between Section C-C and Section D-D.

Determine the point at which the foreslope will begin to transition from a 4:1 foreslope to a 10:1 foreslope. The transition will follow the runout path and begin at the point where the runout path intersects the edge of the finished shoulder (Section A-A.) The runout path can be determined using the runout length as stated in Section III-15.03 – Foreslope Transitions. The foreslope rate in the transition area (Section B-B) should have the same rate as the foreslope in the fill area (Section D-D.)

The 4:1 foreslope becomes the secondary foreslope at the start of the transition area (Section A-A.) The top of the 4:1 foreslope should be at the edge of the 10:1 foreslope along the runout path and the bottom will be where the 4:1 foreslope ties back into the ditch bottom.

Dry Side

Determine which foreslope configuration will be used through the fill area on the dry side. To do this, find the deepest fill height measured from the toe of the foreslope at the tie in with the ditch bottom to the edge of the finished shoulder. Because the roadway is a two-lane state corridor and the design ADT is 1000, Figure 6 will be used. Using the deepest fill height, choose

the best possible foreslope configuration. The most preferred foreslope configuration will be the bottom line. For example, for a fill height of 18', the foreslope configurations in order of preference would be: 1) 4:1 to ditch bottom; 2) 4:1 to clear zone, 24:1 for 12', 3:1 to ditch bottom; and 3) 4:1 to clear zone, 3:1 to ditch bottom. The same foreslope configuration should be used throughout the fill section. The most preferred foreslope configuration should be used unless site conditions do not allow it.

Once the foreslope configuration has been determined, the limits of the fill area can be found (Section D-D.) Sometimes it may not be clear where the fill area begins and ends and may require engineering judgment to determine the limits and/or trial and error to find the best place to fit the foreslope transition.

A 25' transition should be used to transition between Section C-C and Section D-D. The transition ties the existing 4:1 foreslope at Section C-C with the slope configuration in the fill section at Section D-D.

A foreslope transition using the runout length is not needed on the dry side because the existing foreslope and the foreslope in the fill section both have the same slope rate.

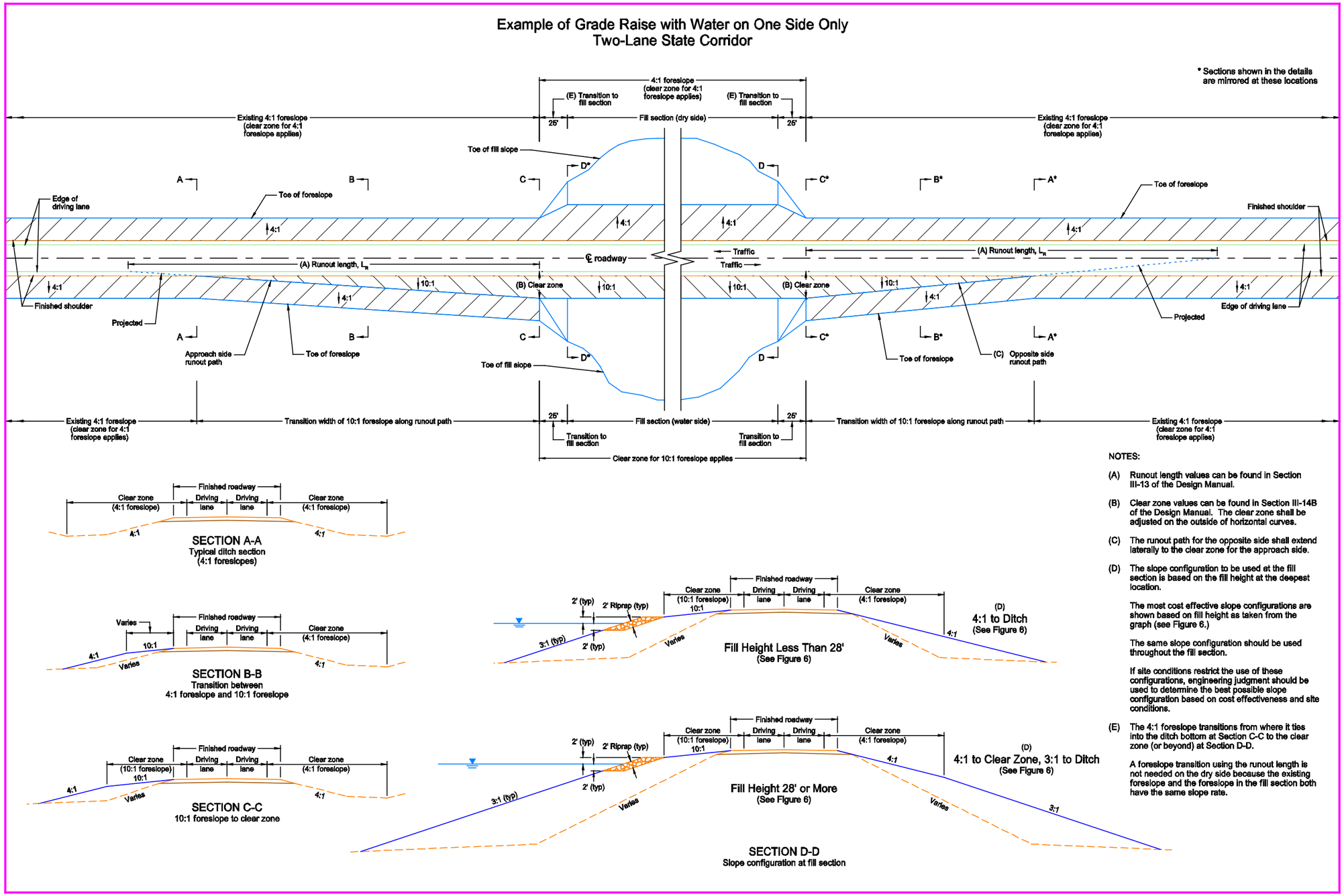

Figure 21 – Example 3 – Grade Raise with Water on One Side Only